MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

FIRST TRIMESTER, 2018/2019

EOP3026 – OPTOELECTRONICS DEVICES

(All Section / Groups)

18 OCTOBER 2018
14:30 P.M - 16:30 P.M.
(2 Hours)

INSTRUCTION TO STUDENTS

1. This examination paper consists of 4 pages including cover page with 4 questions only.

2. Answer **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1 [25 marks]

(a) Sketch a graph of output power versus wavelength of a LED and a laser diode. Explain briefly their differences. [2 + 4 marks]

(b) Draw the band diagrams of a double heterostructure junction LED at zero bias and at forward bias. Explain how the design can improve the overall performance of the LED as compared to a homojunction device. [10 marks]

(c) Suggest a single element or compound semiconductors that can be used for LED and justify your selection. [3 marks]

(d) Briefly explain 3 factors that affect the emission spectra of a LED [6 marks]

Question 2 [25 marks]

(a) (i) Explain the following terms that quantify the performance of a laser diode: external quantum efficiency (QE), external power efficiency (conversion efficiency) and the slope efficiency. [3 marks]

(ii) A laser diode is operating at 1550 nm for use in optical communications. The threshold current is 15 mA. At I = 35 mA, the output optical power is 10 mW, and the voltage across the diode is 2.2 V.
Calculate external quantum efficiency (QE), external power efficiency (conversion efficiency) and the slope efficiency of the laser diode. [6 marks]

(b) Draw a schematic with clear labelling of a quantum well and a multiple quantum well structure for laser diode. Show the electron energy across the device and sketch the corresponding radiation distribution of both structures. Explain briefly the operation principle of a quantum well laser. [6 + 6 marks]

(c) List 4 distinct characteristics of vertical cavity surface emitting lasers (VCSELs). [4 marks]

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Question 3 [25 marks]

(a) The responsivity of an InAs pn junction photodiode for infrared detection is shown in Fig. Q3.

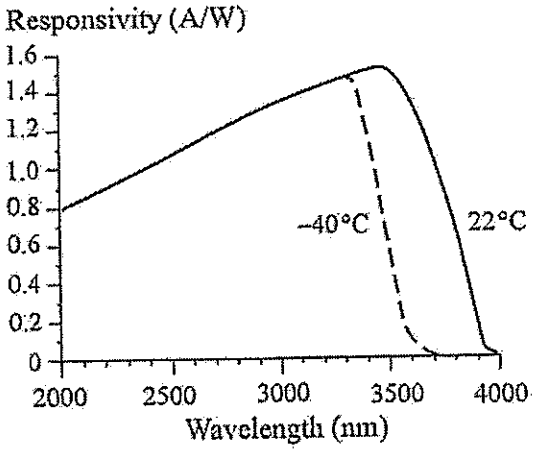

Figure Q3

(i) Calculate the quantum efficiency at the peak responsivity at 22 °C and -40 °C respectively. [4 marks]

(ii) The diode area that is involved in the detection as a diameter of 0.25 mm. What is the intensity of light that corresponds to a photocurrent of 100 nA at -40 °C? [3 marks]

(iii) Deduce the bandgap of InAs. [2 marks]

(iv) What is the cutoff wavelength at 22°C and -40°C respectively? Comment on the difference in cutoff wavelengths at different temperature. [4 marks]

(b) Name a photodetector without gain/multiplication and a photodetector with gain/multiplication. Explain in details with the aid of suitable diagram to show how multiplication is achieved in the photodetector. [2 + 6 marks]

(c) Define noise equivalent power (NEP) of a photodetector. Calculate NEP of a photodetector with dark current of 0.5 μA. Its peak responsivity is 0.7 A/W at 1.55 μm and the total noise current is 4 nA. [4 marks]

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Question 4 [25 marks]

(a) (i) Draw the current-voltage curve of a pn-junction in the dark and under illumination. Label the reverse-biased voltage, open circuit voltage, photocurrent, short circuit current, maximum voltage and current for a solar cell. [5 marks]

(ii) Define "fill factor" which is the figure of merit for the solar cell. [2 marks]

(iii) With the help of suitable diagrams, define the load line and the efficiency of a solar cell. [4 marks]

(iv) Calculate the maximum output power and efficiency of a solar cell with an open circuit voltage of 0.7 V and a short circuit current of 40 mA when illuminated directly with light of intensity 1 kW m^{-2}. The fill factor is 0.7 and the solar cell has an area of 1 cm x 1 cm. [4 marks]

(b) Sketch the IV curve of solar cell with different series resistance: R_a, R_b and R_c where $R_a > R_b > R_c$ and $R_c = 0$. Discuss the effect of series resistance on the performance of solar cells. [5 marks]

(c) Explain a design of a solar cell that can achieve efficiency exceeding the Shockley-Queisser limit. [5 marks]

PHYSICAL CONSTANTS

Speed of light:	$c = 3.0 \times 10^{8}$ m/s
Electronic charge:	$e = 1.6 \times 10^{-19}$ C
Planck's constant:	$h = 6.63 \times 10^{-34}$ Js
Permittivity in vacuum:	$\varepsilon_o = 8.85 \times 10^{-14}$ F/cm
Permeability in vacuum:	$\mu_o = 4\pi \times 10^{-7}$ H/m
Free electron mass:	$m_o = 9.11 \times 10^{-31}$ kg
Boltzmann's constant:	$k_B = 1.3806 \times 10^{-23}$ J/K
Thermal voltage:	$V_t = kT/e = 0.0259$ V

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